 0030-0950/79/0005-0218/$2.00/0

SEASONAL DISTRIBUTION OF PHYTOPLANKTON BIOMASS IN A NEARSHORE AREA OF THE CENTRAL BASIN OF LAKE ERIE, 1975–1976[1]

JOHN E. REUTER[2], Great Lakes Laboratory, State University College at Buffalo, Buffalo, New York 14222

Abstract. Samples for the analysis of seasonal distribution of phytoplankton biomass were collected on 10 occasions between July 1975 and June 1976. Samples were taken from 3 depths in the euphotic zone at 5 nearshore stations in Lake Erie near Ashtabula, Ohio. A bimodal pattern of distribution was observed with fall and spring maxima and the dominance of Bacillariophyceae. Although the maxima were equal in magnitude, the fall peak was longer in duration and was dominated by *Stephanodiscus niagarae* and *Pediastrum simplex.* The spring biomass peak was observed on a single collection date and was composed principally of *Stephanodiscus niagarae, Skeletonema subsalsum, Melosira italica* and *Cyclotella* sp. The Cryptophyta were common throughout the study while representatives of the Cyanophyta and Pyrrhophyta were only abundant in a single collection. The occurrence and distribution of *Skeletonema subsalsum* (Bacillariophyceae) are discussed.

OHIO J. SCI. 79(5): 218, 1979

Increased attention has been given to the seasonal distribution of phytoplankton sampled from the nearshore area of the Central Basin of Lake Erie. Although early studies date back to Vorce (1881) and Burkholder (1929), comprehensive research was sparse until Davis (1954a, b, 1962, 1964, 1965) began a series of investigations in the Cleveland Harbor area. More recent studies, which have focused on the American nearshore, include: FWPCA (1968), Hartley and Potos (1972), Rietz (1973), Garlauskas (1974), Great Lakes Laboratory (1974) and Munawar and Munawar (1975, 1976). In addition, Michalski (1968) investigated the phytoplankton of the Canadian nearshore. The present report examines both quantitative and qualitative aspects of phytoplankton biomass seasonal distribution in the nearshore region (between 20 m isopleth and the shoreline) of Lake Erie in the vicinity of Ashtabula, Ohio.

[1]Manuscript received 22 May 1978 and in revised form 14 March 1979 (#78-27).

[2]Present address: Department of Environmental Studies, University of California at Davis, Davis, CA 95616.

MATERIALS AND METHODS

Phytoplankton samples were taken at approximately 4 week intervals from July to November 1975 and from April to June 1976 at 5 stations (fig. 1). Water was collected with a Van Dorn bottle at 3 depths in the euphotic zone: 1 m below the surface and the depths corresponding to 25% and 1% of the surface light transmission. Light transmittance was determined using a Kahlsico #268WA310 Photometric Submarine Photometer. Due to natural variations in solar illumination, changes in cloud cover and water turbidity, the depth of 1% surface light tranmsittance ranged from 18 m (bottom) on 30 July to 3 m on 16 November. Composite samples were made for each station by combining equal volumes of water from each of the 3 depths sampled for phytoplankton identification and enumeration. Samples were preserved in Lugol's solution (Vollenweider 1969).

The laboratory procedure employed for phytoplankton analysis was that of Utermöhl (1958) as modified by Lorefice (1974). Depending on algal and inorganic particulate density, 10–50 ml of unconcentrated lake water was settled for 24 hours and phytoplankton taxa were counted at 300X with a Wild Heer burg (M-40), Phase Contrast, Inverted Microscope. A minimum of 300 cells were enumerated for each sample (Lund *et al* 1958). Algal biomass was calculated by taking the average dimensions of individual organisms for each collection period and computing the volume of the geometric form which best fit the shape of the cells measured. This volume was subsequently converted to biomass assuming the density of an algal cell to be similar to that of water, 1.0 g/ml (Willen 1959). When colonial forms were encountered, the average number of cells/colony was calculated and multiplied by the cell volume to obtain the volume/colony. Between 25 and 60 cells were measured to account for the natural diversity of size in individuals comprising the phytoplankton community. Biomass computations were made only on organisms that were found more than 3 times in a single sample.

To deal with the numerous problems associated with horizontal heterogeneity (patchiness) of phytoplankton in Lake Erie (Verduin 1951, Davis 1962), estimates of biomass were reported as a mean for the five stations sampled. Further attempts were made to reduce the sampling error due to patchiness by taking triplicate samples in 1975 and duplicate samples in 1976. These procedures would yield a more realistic measure of actual phytoplankton populations because of the continual motion of water within the nearshore lacustrine environment.

Diatom identification was facilitated by the use of permanent slides which were prepared by heating a concentrated sample and a few drops of H_2O_2 on a glass slide followed by mounting in Hyrax (Munawar and Munawar 1976). The species identification of *Skeletonema subsalsum* was kindly done by Dr. Grethe R. Hasle (University of Norway). On each collection date, small ($<10\mu$) flagellated cells were found which could not be positvely identified. Although many of these cells may have belonged to the class Chrysophyceae, identification was uncertain; therefore, these organisms were grouped together under the category unidentified flagellates.

RESULTS

Species composition. A total of 86 algal taxa were identified during the investigation (table 1), a detailed listing which is presented in Reuter (1977). The Chlorophyta represented the most diverse division with 43 taxa encountered. Within this division, the members of the Chlorococcales were most common (36 taxa). The number of taxa representing the Bacillariophyceae (19 taxa), Cyanophyta (10 taxa) and Cryptophyta (5 taxa) was relatively moderate. The Chrysophyceae, Pyrrhophyta and Euglenophyta contributed very little to the total number of observed taxa.

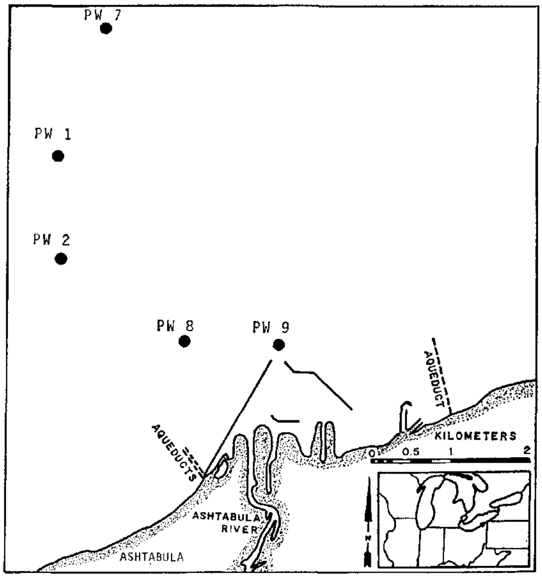

FIGURE 1. Location of sampling stations in the nearshore area of the Central Basin of Lake Erie in the vicinity of Ashtabula, Ohio.

Seasonal variation of total phytoplankton. The investigation was initiated on 10 July 1975 with the first 3 collection dates occurring during what appeared to be a period of summer minimum (fig. 2). Total phytoplankton biomass steadily decreased from 804 mg/m^3 on July 10 to a minimum of 321 mg/m^3 on August 19. The distribution of the major algal groups

TABLE 1

Seasonal Distribution of Total Phytoplankton Biomass and Associated Major Taxa.

Taxa / Collection date	1975 7/10	1975 7/30	1975 8/19	1975 9/14	1975 10/19	1975 11/16	1976 4/9	1976 4/20	1976 5/15	1976 6/10
BACILLARIOPHYCEAE	428(7)*	132(7)	(5)	1146(11)	1005(11)	1178(9)	512(17)	54(13)	1562(15)	(1)
Asterionella formosa	25	—	—	—	—	—	—	—	—	—
Cyclotella sp.	—	—	—	—	—	—	—	—	224	—
Fragilaria crotonensis	403	132	—	56	—	—	40	—	—	—
Melosira italica	—	—	—	—	—	—	—	—	289	—
Skeletonema subsalsum	—	—	—	—	—	—	—	—	340	—
Stephanodiscus binderanus	—	—	—	—	—	—	217	22	56	—
S. niagarae	—	—	—	1025	836	1037	—	—	613	—
Surirella sp.	—	—	—	—	—	—	65	—	—	—
Others	—	—	—	65	169	141	134	32	—	—
CHLOROPHYTA	70(24)	365(33)	182(32)	430(29)	799(23)	354(26)	119(18)	139(18)	83(16)	29(6)
Chlamydomonas globasa	—	—	—	—	—	8	119	125	41	13
Coelastrum reticulatum	—	—	18	18	17	14	—	—	—	—
Oocystis spp.	38	272	22	37	19	11	—	—	14	—
Pediastrum simplex	—	24	80	244	624	191	—	—	—	—
Scenedesmusbijuga var. *flexuosus*	10	26	19	144	29	69	—	—	—	—
Sphaerocystis schroeteri	—	15	31	—	—	—	—	—	—	—
Others	22	28	12	17	110	61	—	14	28	16
CRYPTOPHYTA	270(5)	110(5)	100(5)	119(5)	255(5)	370(5)	47(4)	270(5)	383(5)	270(5)
Cryptomonas erosa	197	45	46	77	142	247	—	98	179	155
C. marssonii	8	5	—	12	20	44	—	—	—	40
Katablepharis ovalis	6	3	7	4	9	8	13	7	8	33
Rhodomonas minuta	41	57	47	26	37	50	34	165	196	42
Others	18	—	—	—	47	21	—	—	—	—
CYANOPHYTA	15(3)	20(4)	14(7)	16(9)	114(5)	11(3)	—	—	14(2)	2(1)
Anabaena spp.	4	8	6	2	29	3	—	—	—	—
Aphanizomenon flos-aquae	8	12	8	14	85	8	—	—	14	—
Others	3	—	—	—	—	—	—	—	—	2
CHRYSOPHYCEAE	2(1)	2(2)	5(1)	3(1)	1(1)	1(1)	10(2)	18(3)	(1)	54(2)
Chrysochromulina parva	2	2	5	3	1	1	—	9	—	54
Dinobryon spp.	—	—	—	—	—	—	10	9	—	—
PYRRHOPHYTA	(2)	(1)	(2)	(2)	(2)	(3)	(1)	265(1)	—	—
Peridinium aciculiferum	—	—	—	—	—	—	—	265	—	—
EUGLENOPHYTA	—	—	—	—	—	—	(2)	—	(1)	—
Unidentified flagellates	19	26	20	35	96	41	49	147	154	105
TOTAL	804(42)	655(52)	321(52)	1749(57)	2270(47)	1955(47)	757(45)	893(43)	2196(40)	460(15)

*Values are mg/m^3 and numbers in parentheses( ) show the total number of taxa found on a given collection date.

also differed during this period (fig. 2). On July 10 the Bacillariophyceae and Cryptophyta were the most abundant phytoplankters. By July 30 the Bacillariophyceae had declined and the Chlorophyta became the dominant algal group. In the August 19 samples, only the Chlorophyta were present in appreciable quantities.

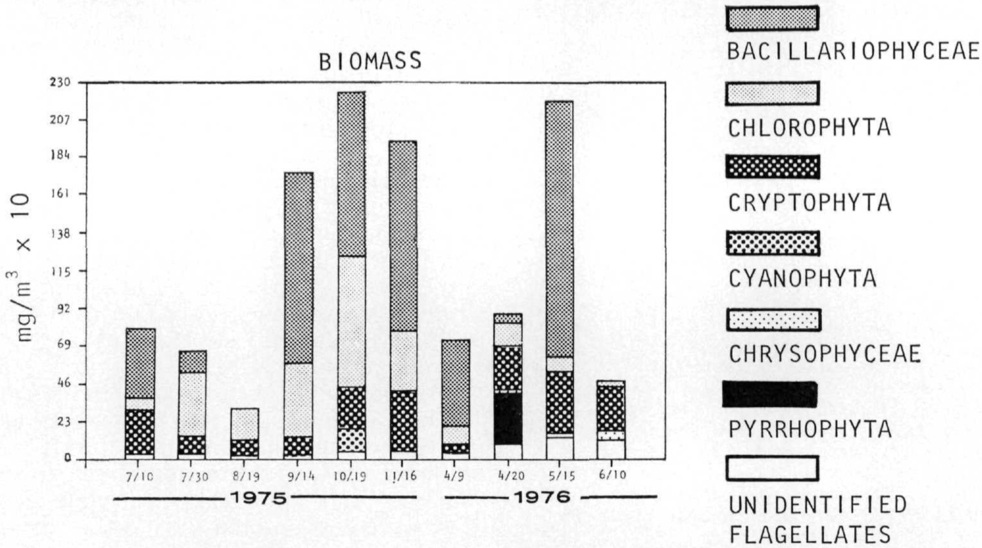

FIGURE 2. Seasonal distribution of total phytoplankton biomass and associated major algal groups.

During the fall collection dates (Sept. 14, Oct. 19, Nov. 16) a biomass maximum was observed. Biomass values rose to 1749 mg/m^3 on Sept. 14 and remained high during the two subsequent sampling dates (2270 mg/m^3 on Oct. 19 and 1955 mg/m^3 on Nov. 16. Due to the limited sampling regime, the exact duration of the biomass maximum was impossible to determine. The Bacillariophyceae were the most abundant phytoplankters during the fall, and Chlorophyta biomass was also high at that time. The composition of the phytoplankton community remained relatively uniform on the 3 collection dates with the exception of an increase of Cyanophyta on Oct. 19th.

On the first collection during the spring of 1976 (April 9) a phytoplankton biomass of 737 mg/m^3 was observed of which the Bacillariophyceae were dominant taxa encountered. Although biomass was similar on April 20 (893 mg/m^3), community composition changed (fig. 2). The Cryptophyta and Pyrrhophyta dominated the phytoplankton, while the Chlorophyta and unidentified flagellates contributed lesser numbers. The May 15 sample was characterized by a large increase in biomass (2196 mg/m^3). The Bacillariophyceae were by far the most abundant group, but the Cryptophyta were again present in substantial quantities. In what appeared to be a return to the summer minimum, biomass dropped to 460 mg/m^3 on June 10 with the Cryptophyta and unidentified flagellates dominating the biomass.

Seasonal variation of the major algal groups and common species. The Bacillariophyceae were the most abundant phytoplankters and a definite bimodal pattern of seasonal distribution was observed with maxima occurring in the fall and spring (table 1, 2). On July 10, Bacillariophyceae biomass was 428 mg/m^3 of which *Fragilaria crotonensis* contributed 403 mg/m^3. A marked reduction in biomass (132 mg/m^3) was observed on July 30 when *F. crotonensis* was the only taxon encountered. By August 19 this group was absent from the samples. During the fall collection dates biomass increased to approximately 1100 mg/m^3. This increase was singularly attributable to *Stephanodiscus niagarae* obtaining biomass values ranging from 836 to 1037 mg/m^3. The spring collections of 1976 differed from the 1975 summer and fall collections in that a variety of taxa composed the Bacillariophyceae community with no single taxon dominating. On April 9, *Stephanodiscus binderanus*, *Surirella* sp., *Asterionella formosa* and *Fragilaria crotonensis* were the most common taxa contributing 512 mg/m^3 to the biomass. Biomass decreased to less than 100 mg/m^3 on April 20. A spring increase was observed on May 15 when Bacillariophyceae biomass dramatically increased to 1562 mg/m^3, the highest biomass value for any major algal group during the investigation. *Stephanodiscus niagarae*, *Cyclotella* sp., *Melosira italica* and *Skeletonema subsalsum* were the major constituents of the phytoplankton during the biomass maximum. With the exception of *S. niagarae*, the dominant Bacillariophyceae observed during the spring were not encountered during the other collection dates. The spring diatom increase was observed only on May 15 and, by June 10, no Bacillariophyceae were found in the samples.

TABLE 2

Seasonal Distribution of the Most Common algae Which Contributed 5% or More to the Total Phytoplankton Biomass.

Collection Date	Species	Mean % Biomass
7/10/75	*Fragilaria crotonensis*	50.1
	Cryptomonas erosa	24.7
	Oocystis spp.	5.4
	Rhodomonas minuta	5.2
7/30/75	*Oocystis* spp.	42.4
	Fragilaria crotonensis	20.0
	Rhodomonas minuta	9.8
	Cryptomonas erosa	6.7
8/19/75	*Pediastrum simplex*	25.9
	Rhodomonas minuta	14.6
	Sphaerocystis schroeteri	9.5
	Cryptomonas erosa	9.3
	Oocystis spp.	7.3
	Scenedesmus bijuga var. *flexuosus*	6.0
	Cryptomonas marssonii	5.7
	Coelastrum reticulatum	5.0
9/14/75	*Stephanodiscus niagarae*	58.7
	Pediastrum simplex	14.5
	Scenedesmus bijuga var. *flexuosus*	6.6
10/19/75	*Stephanodiscus niagarae*	36.9
	Pediastrum simplex	27.6
	Cryptomonas erosa	6.3
	Aphanizomenon flos-aquae	5.1
11/61/75	*Stephanodiscus niagarae*	53.3
	Cryptomonas erosa	12.7
	Pediastrum simplex	10.1
4/ 9/76	*Stephanodiscus binderanus*	28.7
	Chlamydomonas globosa	16.1
	Stephanodiscus tenuis	11.0
	Surirella sp.	9.9
	Asterionella formosa	6.8
4/20/76	*Peridinium aciculiferum*	35.1
	Rhodomonas minuta	18.0
	Chlamydomonas globosa	14.5
	Cryptomonas erosa	11.2
5/15/76	*Stephanodiscus niagarae*	27.6
	Skeletonema subsalsum	15.6
	Melosira italica	14.4
	Cyclotella spp.	10.2
	Rhodomonas minuta	8.8
	Cryptomonas erosa	8.3
	Unidentified Flagellates	6.9
6/10/76	*Cryptomonas erosa*	32.1
	Unidentified Flagellates	26.4
	Chrysochromulina parva	11.0
	Rhodomonas minuta	8.8
	Cryptomonas marssonii	7.7
	Katablepharis ovalis	7.0

A unimodal pattern of distribution with a definite fall maximum was observed for the Chlorophyta (table 1). A number of taxa were abundant in the summer and fall collection; while very few were encountered during the spring. On July 10, biomass was low (70 mg/m^3) with *Oocystis* spp. as the dominant taxa. Biomass increased to 365 mg/m^3 on July 30 due to a large increase of *Oocystis* spp.; *Pediastrum simplex* var. *duodenarium*, *Sphaerocystis schroeteri* and *Scenedesmus bijuga* var. *flexuosus* were also present on this date but in lesser quantities. By August 19, total Chlorophyta biomass decreased as did that of *Oocystis* spp. The fall samples were characterized by large increases in *Pediastrum simplex* var. *duodenarium* and to a lesser extent, *Scenedesmus bijuga* var. *flexuosus*. On Oct. 19, a maximum biomass of total Chlorophyta (799 mg/m^3) and *Pediastrum simplex* var. *duodenarium* (624 mg/m^3) was observed. *Pediastrum simplex* var. *duodenarium* biomass decreased on Nov. 16 and was associated with a decline in total Chlorophyta biomass. The spring collections were quite different in both quantity and composition. On April 9, biomass was only 119 mg/m^3 with only *Chlamydomonas globosa* observed. *Chlamydomonas globosa* remained the dominant taxon for the duration of the spring collections but was virtually absent from the summer and fall samples. *Oocystis* spp. was again observed on May 15 and June 10 but in reduced numbers.

Although 5 species of Cryptophyta were identified, only *Rhodomonas minuta* and *Cryptomonas erosa* contributed appreciably to the total biomass of this division (table 1). *Cryptomonas erosa* (197 mg/m^3) was the dominant species on July 10, while total Cryptophyta biomass was 270 mg/m^3. Values decreased to approximately 110 mg/m^3 by July 30 and remained relatively uniform for the next three collection dates. In these samples, both *Rhodomonas minuta* and *Cryptomonas erosa* occurred in nearly equal numbers. Biomass increased to 255 mg/m^3 and 370 mg/m^3 on Oct. 19 and Nov. 16 respectively. This increase was attributed to an increase in biomass of *Cryptomonas erosa* which was the dominant cryptomonad found at that time. A decrease in biomass occurred during the first spring sampling; and, for the first time in the study, *Cryptomonas erosa* was not observed. On April 20 total Crypotphyta biomass increased to 270 mg/m^3 and was associated with an increase of *Rhodomonas minuta*. Biomass values again increased to 383 mg/m^3 on May 15 at which time *Rhodomonas minuta* and *Cryptomonas erosa* were present in nearly equal numbers. A biomass decrease to 270 mg/m^3 was observed on June 10. *Katablepharis ovalis* and *Cryptomonas marssonii* were the major contributors to the Cryptophyta population during this sampling period.

Except for the October 19 collection when a biomass of 114 mg/m^3 was observed, the Cyanophyta were virtually absent from the samples (table 1). For the remaining collection dates, Cyanophyta biomass never exceeded 20 mg/m^3. *Aphanizomenon flos-aquae* was the most common taxa encountered, while *Anabaena* spp. occurred less commonly.

Due to the small size of the unidentified flagellate cells, their biomass values were relatively small (table 1). For the summer and fall samples, biomass never exceeded 60 mg/m^3. Biomass values of the unidentified flagellates increased on April 20 and remained fairly uniform at approximately 120 mg/m^3 for the remainder of the study. The only collection in which the Pyrrhophyta were encountered was April 20 when a biomass of 265 mg/m^3 was observed with only *Peridinium aciculiferum* occurring in the sample.

Chrysochromulina parva and *Dinobryon* spp. were the only Chrysophyceae taxa identified in the samples, with their biomass never greater than 60 mg/m^3 on any collection date (table 1). Although *Chrysochromulina parva* was observed in each of the summer and fall samples, its biomass was negligable (<10 mg/m^3). Biomass values increased slightly on April 9 and April 20 due to the occurrence of *Dinobryon* spp. which was observed only on these two dates. The two taxa were absent from the May 15 samples. On June 10, *Chrysochromulina parva* biomass increased to nearly 55 mg/m^3 during what appeared to be a bloom condition. At that time, cell concentrations were greater than 4000 cells/ml, the highest values observed for a single species in this study.

DISCUSSION

Previous observations of phytoplankton distribution in the Central Basin lack uniformity of 1. sampling location, 2. method of phytoplankton collection and concentration, and 3. method of calculating standing crop abundance. In past studies, sampling location varied from water taken at a single fixed point such as water intake systems (Davis 1964, Michalski 1968, Rietz 1973) to synoptic multi-station sampling (Davis 1954a, 1962, Great Lakes Laboratory 1974). Earlier studies also differed with respect to sampling depth and geographic location. The results of studies based on various methods of phytoplankton collection (net samples and whole water samples) and concentration (settling, straining and centrifugation) are not directly comparable to the present study. Estimates of phytoplankton abundance using microscopic techniques have been expressed in numerous ways, including cell number, cell volume or biomass and cell surface area. Due to the great diversity in phytoplankton size, the results of these studies are difficult to directly compare. Therefore, only the general trends of phytoplankton abundance and composition will be discussed in relation to past investigations.

The bimodal pattern of distribution observed in my study was in agreement with that reported by Davis (1954a, 1962) and the Great Lakes Laboratory (1974). Periods of maximum biomass were observed by these investigators in the spring (March-May) and fall (September-November). Other researchers, examining the nearshore phytoplankton of the Central Basin, have reported the occurrence of trimodal peaks. Munawar and Munawar (1975) observed periods of maximum phytoplankton abundance during April, July-August, and December; while periods of minimum concentration were observed in May and October. Garlauskas (1974) observed a single peak in September composed primarily of the genus *Ceratium*.

The seasonal succession of the major algal groups during the 1975–1976 survey were similar to that previously reported by Davis (1962) and Munawar and Munawar (1975, 1976). During 1975–1976, the Pyrrhophyta were never found to be important contributors to phytoplankton biomass. This was observed by Davis (1954a, 1962) and the Great Lakes Laboratory (1974); while Munawar and Munawar (1975) found this group to be relatively abundant in July, September and November.

Quantitatively, the biomass values reported in the present study were considerably lower than those of other investigations. The Great Lakes Laboratory (1974) reported biomass values in the range of 900–5700 mg/m^3 for the nearshore area in the vicinity of Cleveland, Ohio; while Munawar and Munawar (1975) note values between 2000–8000 mg/m^3 for the same geographic area. Glooschenko *et al* (1974) encountered higher values of chlorophyll *a* in the vicinity of Cleveland than in most other areas of the Central Basin and attributed this to nutrient discharge into the surrounding waters. This explanation possibly may be applicable for the differences observed in phytoplankton biomass between Ashtabula and Cleveland.

Individual phytoplankters as well as major algal groups demonstrated patterns of seasonal succession during this investigation. *Fragilaria crotonensis* was a dominant taxon during the summer collection periods as well as *Oocystis* spp. Large quantities of *Fragilaria crotonensis* were found only on July 9 and 30 collection dates. Munawar and Munawar (1976) found large amounts of this species in June-July 1970, but also observed *F. crotonensis* in high numbers through the month of September.

Following the summer biomass minimum, a fall maximum was observed first on September 14. On the collection dates from September 14 to November 16, both phytoplankton composition and biomass remained relatively constant. The dominant taxa observed during that period were, the diatom, *Stephanodiscus niagarae* and the green alga *Pediastrum simplex* var. *duodenarium*. These taxa were also found to be dominant fall phytoplankters in previous years (Davis 1962). Munawar and Munawar (1975) report that *Stephanodiscus niagarae* contributed 56% of the biomass in the fall, while the percent composition of *Pediastrum simplex* was somewhat lower than that reported in this study. The abundance of the Cyanophyta in the fall was also in agreement with past reports of the seasonal distribution of this group.

For both the summer and fall collections a large number of taxa belonging to the Chlorophyta were important contributors to total biomass; while, during the spring collections, *Chlamydomonas globosa* was the single dominant species. Also during the spring sampling period, a number of algae were observed that were not encountered in the summer or fall collections. These taxa included: *Peridinium aciculiferum*, *Stephanodiscus binderanus*, *Skeletonema subsalsum*, *Melosira italica*, *Surirella* sp. and *Cyclotella* sp. Along with *Stephanodiscus niagarae*, other algae that were abundant during the May 15 biomass maximum were *Melosira italica*, *Skeletonema subsalsum*, *Cyclotella* sp., *Rhodomonas minuta* and *Cryptomonas erosa*. It is interesting to note that the spring maximum was composed of a number of abundant phytoplankters while only two species were prevalent during the fall maximum.

The occurrence of *Skeletonema subsalum* in Lake Erie was recently reported (Hasle and Evensen 1975), and data on its seasonal abundance and distribution are limited. A related species, *Skeletonema potamos* (=*Microsiphonia potamos*), was reported from the Western Basin of Lake Erie by the Center for Lake Erie Area Research (1975); however, because these two species are morphologically similar and have been found to occur together in Lake Erie (Hasle and Evensen 1976), no attempt was made during the present study to separate them taxonomically. According to Hasle, one reason for the lack of published records for freshwater species of the genus *Skeletonema* might have been a possible confusion between this genus, *Melosira* and *Stepahnodiscus.* This may account for the lack of observations of *Skeletonema* during previous investigations in the Central Basin.

Munawar and Munawar (1975, 1976) stressed the importance of phytoflagellates in Lake Erie. In the present study, the distribution of the Cryptophyta was unique with respect to the other major algal groups in that members of this group were present throughout the investigation in relatively uniform quantities. This pattern of distribution is in general agreement with that of Munawar and Munawar as was the large biomass of *Chrysochromulina parva* observed in June.

Acknowledgments. This study was part of an M.A. thesis submitted to the Biology Dept., State University College at Buffalo, Buffalo, New York. I am grateful to R. W. Flint and R. A. Sweeney for their advice and encouragement and to V. R. Frederick and R. A. Sweeney for reading and commenting on this manuscript. I am also indebted to the staff of the Great Lakes Laboratory for their assistance in the collection of samples. Funding for this research was provided through a contract to the Great Lakes Laboratory by the Waterways Experiment Station of the U.S. Army Corps of Engineers (Grant #21-6040-A).

LITERATURE CITED

Burkholder, P. R. 1929 Microplankton studies in Lake Erie. Bull. Buffalo Soc. Nat. Sci. 14: 73–93.

Center for Lake Erie Area Research 1975 Aquatic ecology investigations of a potential power plant site on Sandusky Bay. Appendix B. Plankton and Benthos data. Ohio State University, Columbus, OH. 281 p.

Davis, C. C. 1954a A preliminary study of the plankton of the Cleveland Harbor area, Ohio. II. Distribution and quantity of phytoplankton. Ecol. Monog. 24: 321–347.

——— 1954b A preliminary study of the plankton of the Cleveland Harbor area, Ohio. III. The zooplankton, and general ecological considerations of phytoplankton and zooplankton production. Ohio J. Sci. 54: 388–408.

——— 1962 The plankton of the Cleveland Harbor area of Lake Erie in 1956–57. Ecol. Monog. 32: 209–247.

——— 1964 Evidence for the eutrophication of Lake Erie from phytoplankton records. Limnol. Oceanogr. 9: 275–283.

——— 1965 The standing stock of phytoplankton in Lake Erie at Cleveland, Ohio, 1964. Info. Bull. Planktol. Japan 12: 51–53.

Federal Water Pollution Control Administration (FWPCA) 1968 Lake Erie environmental summary, 1963–1964. U.S. Dept. Interior, Great Lakes Region. Cleveland Program Office. pp. 112–120, 137–143.

Garlauskas, A. B. 1974 Water quality basement for the Cleveland area-Lake Erie. Vol. I. Synthesis. Office of the Great Lakes Coordinator. U.S.E.P.A. Region V, Chicago, Ill. 158 p.

Glooschenko, W. A., J. E. Moore and R. A. Vollenweider 1974 Spatial and temporal distribution of chlorophyll *a* and pheopigments in surface waters of Lake Erie. J. Fish. Res. Board Canada 31: 265–274.

Great Lakes Laboratory 1974 Airport feasibility study for the Lake Erie Regional Transportation Authority. State University College, Buffalo, NY. Report No. 6-5. pp. 43–53, 229–240, 242.

Hartley, R. P. and C. P. Potos. 1972 Algae-temperature-nutrient relationships and distribution in Lake Erie, 1968. U.S.E.P.A. Federal Water Quality Administration. Great Lakes Region, Lake Erie Basin Office, Cleveland, OH. 87 p.

Hasle, G. R. and D. L. Evensen 1975 Brackish-water and fresh-water species of the diatom genus *Skeletonema* Grev. I. *Skeletonema subsalsum* (A. Cleve) Bethge. Phycologia. 14: 283–297.

——— 1976 Brackish-water and fresh-water species of the diatom genus *Skeletonema*. II. *Skeletonema potamos*. J. Phycol. 1: 73–82.

Lorefice, G. J. 1974 Phytoplankton biomass and the thermal bar for the surface waters of Southwestern Lake Ontario, April to May 1972. Unpublished M.A Thesis, Bio. Dept., State University College, Buffalo, NY. 68 p.

Lund, J. W. G., C. Kipling and E. O. LeCren 1958 The inverted microscope method of estimating algal numbers and the statistical basis of estimating by counting. Hydrobiologia 9: 143–170.

Michalski, M. F. P. 1968 Phytoplankton levels in Canadian nearshore waters of the lower Great Lakes. Proc. Conf. Great Lakes Res. 11: 85–95.

Munawar, M. and I. F. Munawar 1975 The abundance and significance of phytoflagellates and nannoplankton in the St. Lawrence Great Lakes. I. Phytoflagellates. Verh. Int. Verein. Limnol. 19: 705–723.

——— 1976 A lakewide study of Phytoplankton biomass and its species composition in Lake Erie, April-December, 1970. J. Fish. Res. Board Canada 33: 581–600.

Reuter, J. E. 1977 Studies of phytoplankton seasonal distribution in a nearshore area of the Central Basin of Lake Erie, 1975–1976. Unpublished M.A. Thesis, Bio. Dept., State University College, Buffalo, NY. 78 p.

Rietz, R. D. 1973 Distribution of phytoplankton and coliform bacteria in Lake Erie. Ohio E.P.A., Division of Surveillance, Columbus, OH. 67 p.

Utermöhl, H. 1958 Zur Verlkommungder quantitatven phytoplankton. Methodik. Mitt. Int. Verein. Limnol. 9: 1–38.

Verduin, J. 1951 A comparison of phytoplankton data obtained by a mobile sampling method with those obtained from a single station. Amer. J. Bot. 38: 5–11.

Vollenweider, R. A. 1969 A manual on methods for measuring primary production in aquatic environments. IBP Handb. No. 12. Blackwell Scientific Publications, Oxford. 213 p.

Vorce, C. M. 1881 Forms observed in waters of Lake Erie. Proc. Amer. Soc. Micros. 4th Annual Meeting. pp. 51–60.

Willen, T. 1959 The phytoplankton of Gorwälm, a bay of Lake Malaren. Okios 10: 241–274.